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Enhancing geometry learning through project-based teaching materials: A focus on circumference and area of circles

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Abstract.
This study aims to develop a Student Worksheet based on the Project-Based Learning (PjBL) approach, ensuring its validity, practicality, and effectiveness in facilitating mathematics instruction on the topic of circumference and area of circles for MTs students. The research follows a Research and Development (R&D) methodology, employing the ADDIE development model, which encompasses five stages: Analysis, Design, Development, Implementation, and Evaluation. The validation process assessed the worksheet's quality across four aspects: content feasibility, material presentation, worksheet structure, and linguistic quality. The results indicate that the content feasibility scored 84%, material presentation 86.5%, worksheet elements 86%, and linguistic quality 88%, all within the "very valid" category. Overall, the Student Worksheet achieved a validity score of 86% (categorized as "very valid"), confirming its appropriateness for use in the classroom. These findings suggest that the PjBL-based Student Worksheet effectively supports mathematics learning and meets expert criteria for validity.

Keywords:
Student worksheets; project-based learning; circumference; area; circle

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INTRODUCTION

Mathematics education plays a pivotal role in shaping students' cognitive development, particularly in fostering their comprehension of mathematical concepts and reasoning about their interrelationships. The curriculum should equip students with the ability to think logically, analytically, systematically, critically, and creatively, as well as develop effective collaboration skills (Suryadi, 2012). Through mathematics instruction, students are encouraged to gain understanding through both concrete and abstract experiences that illustrate the properties of a specific set of objects. This foundational knowledge serves as a crucial basis for developing higher-order thinking skills, which are essential for students in the contemporary era (OECD, 2019).

In the learning process, instructional materials are a key component that supports students' academic success. Efficient teaching materials not only enhance students' comprehension but also foster a sense of independence in their learning endeavors (Trianto, 2011). One type of effective teaching material is the student worksheet, which is tailored to meet the specific needs and characteristics of students. Student worksheet facilitates students' systematic understanding of concepts through clear and contextualized steps.

However, based on the researcher's observations, students continue to encounter challenges in comprehending the learning materials independently, particularly in the area of Circumference and Area of a Circle. Although this material is considered fundamental in geometry, many students have not achieved a satisfactory level of understanding. This is evident in the low scores obtained

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by students when presented with problems related to circles. The difficulties encountered by students in solving problems involving the circumference and area of a circle are attributed to the inadequate teaching materials employed. Teachers often rely on readily available teaching materials without further refinement that aligns with the students' learning needs.

Observations during the learning process revealed a lack of active student engagement, characterized by a scarcity of questions and responses to teacher inquiries. This absence of student participation hinders comprehension and limits students' understanding of the material. The absence of contextual and interactive teaching materials further exacerbates this issue. Consequently, the development of teaching materials tailored to students' needs, such as context-based student worksheets, presents a relevant solution for enhancing students' comprehension and learning outcomes on the topic of circumference and area of circles.

Teaching materials are a fundamental component of the learning process at all educational levels. As elucidated by Alt et al. (2023), Priyana (2019), and Sagala (2013), teaching materials facilitate the acquisition of competencies or basic competencies in a structured and systematic manner, enabling students to master these competencies comprehensively and integrally. As a primary resource in learning, teaching materials encompass information, tools, and texts utilized by teachers for planning and implementing learning activities. Therefore, selecting appropriate teaching materials is paramount to determining the success of the learning process. Teachers must select materials that align with their teaching approach or model, ensuring that the material resonates with students (Octariani & Rambe, 2018).

Teaching materials also serve as guides and references in learning processes grounded in real-world contexts encountered by students. One effective form of teaching material is the Student Worksheet. These worksheets are designed to assist students in comprehending learning materials and solving problems either independently or collaboratively. For instance, in mathematics education, the development of student worksheets tailored to students' needs and implemented through active learning models can effectively facilitate students' understanding of the concepts of circumference and area of circles.

Student worksheets serve as instructional guides for students to engage in investigative activities or problem-solving tasks. These worksheets can be designed to enhance students' cognitive abilities or as practical guides for activities such as experiments or demonstrations (Mutia & Prasetyo, 2018; Prastowo, 2013). Furthermore, student worksheets offer benefits in activating students, facilitating comprehension of the material, and enhancing the efficacy of the learning process. By utilizing student worksheets, students not only acquire knowledge passively but also actively construct their understanding through exploration and discussion. Therefore, the development of student worksheets that align with students' learning styles and relevant teaching methodologies is essential for improving learning outcomes.

The development of student worksheets is a strategic initiative to elevate the quality of learning. Based on the researcher's observations, the current student worksheets in use do not adequately support students' independent knowledge construction. Existing worksheets primarily focus on defining concepts, followed by example problems and repetitive exercises. The presentation of dense and monotonous material leads to a lack of motivation among students to develop critical and creative thinking abilities. Additionally, the use of black-and-white images in the worksheets diminishes their visual appeal and reduces their effectiveness in capturing students' attention (Afriza & Risnawati, 2013).

Student worksheets play a pivotal role in engaging students throughout the learning process. They can facilitate students' concept development, train process skills, and enrich their understanding of the concepts being learned through structured learning activities. In their development, student worksheets should be designed to support teaching models that encourage active student involvement, such as the Project-Based Learning (PjBL) model.

The Project-Based Learning (PjBL) model is an innovative educational approach that fosters critical thinking, problem-solving, planning, and decision-making abilities (Ndiung & Menggo, 2024; Lesmana et al., 2023; Cheng et al., 2022). By implementing PjBL, traditional learning

methods can be transformed into more contextual and meaningful experiences. PjBL encourages students to produce innovative work that is relevant to their daily lives and contributes to the development of science, technology, and the arts.

As a project-based learning model, PjBL provides an engaging and meaningful learning experience. Issa and Khataibeh (2021), Almulla (2020), and Istarani (2011) elucidates that PjBL emphasizes complex and contextual learning activities, where students actively participate. In this model, the teacher serves as a facilitator and mentor, guiding students in comprehending concepts through exploration and hands-on activities. This approach empowers students to think creatively, collaborate in groups, and generate practical solutions to the challenges they encounter.

By integrating PjBL into the development of student worksheets, students are not only encouraged to actively engage in learning but also gain a deeper and more enjoyable learning experience. It is anticipated that this approach will enhance students' motivation to learn, strengthen their conceptual understanding, and develop essential 21st-century skills such as collaboration and creativity.

A study conducted by Farika and Sopyan (2015) demonstrated that Project-Based Learning (PjBL)-based Student Worksheets (LKS) can enhance students' problem-solving abilities in the context of reflection. The PjBL-based LKS developed in their study was specifically designed to improve students' critical thinking skills through project-based activities. The study's findings revealed that the implementation of PjBL-based LKS was not only effective in facilitating students' comprehension of the material but also in training their problem-solving skills. Another study by Khotimatuzzahara et al. (2021) further supports this notion by demonstrating that Project-Based Learning (PBL)-based Learning Knowledge Skills (LKS) is regarded as a teaching material capable of assisting educators in delivering diverse learning materials beyond the conventional curriculum. Furthermore, it facilitates student development in searching, locating, and integrating acquired knowledge, enabling them to solve problems posed by the instructor by producing tangible products from the learning outcomes. The positive student response to PjBL-based LKS in this study underscores the project-based approach's ability to provide a more engaging and pertinent learning experience. Furthermore, Novita et al. (2016) developed PjBL-based LKS for the triangle material at the junior high school level, and Hasna et al. (2024) conducted the development of an e-LKS. This research culminated in the creation of a valid LKS product based on evaluations of its content, construct, and language. These findings underscore the paramount importance of the validity of teaching materials in ensuring their effectiveness in fostering learning outcomes.

Although these studies demonstrate the efficacy of Project-Based Learning (PjBL)-based Learning Kinematics (LKS) in enhancing student learning outcomes, several limitations present a research gap for further investigation. Previous studies have predominantly focused on materials such as reflections, colloids, or triangles. There has yet to be a study that specifically develops PjBL-based LKS for the geometry material of circumference and area of circles. This material holds substantial potential for integration into real-world contexts, such as garden design or cultural art patterns in circular forms. Previous studies have been conducted in specific locations and with particular subjects, whose student characteristics may differ. The adaptation of PjBL-based teaching materials for diverse locations, considering the local students' needs and characteristics, has not been extensively explored. Based on these considerations, the present study aims to develop a valid, practical, and effective Project-Based Learning-based Student Worksheet for utilization in the mathematics learning process on the material of circumference and area of circles.

METHOD

This study employs a Research and Development (R&D) approach to develop a student worksheet based on Project-Based Learning (PjBL) for the topics of circumference and area of a circle. The development model employed in this study is the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was chosen because it provides clear and structured guidance for each phase of developing

dynamic and effective instructional materials.

Analysis

In the analysis phase, an identification of the students' needs, the material to be taught, and the characteristics of the school and learners was conducted. The researcher conducted observations at MTsN 2 Padangsidimpuan, located in the Padangsidimpuan Tenggara district, to examine the facilities and infrastructure that support mathematics learning. These observations aimed to identify the limitations present in the field as well as potential resources that could be utilized in the development of instructional materials. Aspects observed included classroom space, teaching equipment, and the overall context and conditions that influence the learning process.

Design

In the design phase, the student worksheet based on PjBL was developed with careful consideration of the needs and characteristics of the students, which had been previously analyzed. The Learning Key Skills (LKS) was designed to integrate the concepts of circumference and area of a circle with project-based activities that are relevant to the students' daily lives. Each task and instruction were designed to encourage students to think critically, creatively, and collaborate in solving problems related to the content being taught.

Development

In the development phase, the designed Student Worksheet underwent initial testing on a small scale to evaluate its feasibility and effectiveness in the learning process. This trial involved a small group of students who represented a broader population. Feedback received from students and teachers was utilized to enhance and refine the Student Worksheet before its wider adoption in the teaching process.

Implementation

During the implementation phase, the developed Student Worksheet was implemented in a larger classroom setting for mathematics instruction. Students were assigned project-based tasks related to the topics of circumference and area of a circle. In this phase, the researcher observed the students' reception of the Student Worksheet, their level of engagement in the learning activities, and the effectiveness of the Student Worksheet in enhancing their comprehension of the material. Additionally, data collection through surveys was conducted to assess students' responses to the PjBL-based learning approach.

Evaluation

In the evaluation phase, the validity, practicality, and effectiveness of the developed Student Worksheet were assessed. Evaluation was conducted employing various analytical techniques, as outlined in the subsequent section.

Validity Analysis

The validity of the Student Worksheet (LKS) was assessed by a panel of validators comprising subject matter experts, learning experts, and education practitioners. Each validator evaluated various aspects of the LKS, including its content, structure, language, and alignment with learning objectives. The validity percentage was calculated using the following formula:

$$\text{Validity percentage} = \frac{\sum \text{Given Score}}{\sum \text{ideal score}} \times 100\%$$

Practicality Analysis

To assess the practicality of the Student Worksheet, a limited trial was conducted in the classroom. Students were instructed to utilize the LKS during the learning process and provide feedback via a questionnaire. The data collected from this questionnaire were analyzed to

determine the ease of use for students and its alignment with their learning needs. The questionnaire scores were subsequently calculated to obtain the practicality percentage.

Effectiveness Analysis

The effectiveness of the LKS was measured by analyzing students' learning outcomes before and after its implementation. Pretest and posttest assessments were administered, and the results were analyzed to assess students' improvement in understanding the material. The analysis process involved recording the scores for each question answered by students, calculating the total scores obtained by each student, and computing the class's average score using the following formula:

$$\bar{x} = \frac{\sum x}{N}$$

Where $\bar{x}$ represents the average score, $\sum x$ denotes the total sum of all students' scores, and N represents the number of students who participated in the test. The categorization of students' learning outcomes was based on the Minimum Completion Criteria (KKM), which was set at 75%. The Student Worksheet is considered effective if the percentage of students achieving the minimum completion criteria is satisfactory.

Data collection in this study employed several key techniques: observation, which was conducted to observe the learning conditions at MTsN 2 Padangsidimpuan, including the facilities and resources that support the learning process; questionnaire, which was administered to students to assess their responses to the Project-Based Learning (PjBL)-based Student Worksheet. The questionnaire contained questions regarding student engagement, difficulties in using the Student Worksheet, and their satisfaction with this learning approach; test, where pretests and posttests were used to measure the improvement in students' learning outcomes after using the PjBL-based Student Worksheet in the teaching of the material on the circumference and area of circles.

By employing a clear and systematic method, this study aims to develop a PjBL-based Student Worksheet that is not only valid and practical but also effective in enhancing students' understanding of mathematical concepts, particularly the circumference and area of circles.

RESULTS AND DISCUSSION

The product developed in this study is a Student Worksheet based on Project-Based Learning (PBL) on the circumference and area of a circle. This study adheres to the stages of research and development (R&D), which encompass five primary phases of the ADDIE methodology: analysis, design, development, implementation, and evaluation.

Analysis

At this juncture, the researcher conducted an analysis of two primary aspects: student analysis and analysis of the student worksheets utilized. Student analysis entails examining student characteristics, both in terms of their mathematical proficiency and academic aptitudes. Based on the outcomes of this analysis, it is evident that the majority of students exhibited suboptimal performance on the competency tests. In problem-solving endeavors, students predominantly rely on the example questions provided and encounter difficulties when confronted with slightly modified questions. Notably, they encounter challenges in addressing story problems related to the circumference and area of a circle. This suggests that their comprehension of the material remains restricted. Furthermore, their mathematical knowledge, particularly concerning the circumference and area of a circle, as well as their overall interest in mathematics education, necessitates enhancement.

This analysis underscores the persistent need to address student characteristics, particularly their mathematical and academic aptitudes. The observation that the majority of students exhibited suboptimal performance on competency tests suggests a limited comprehension, particularly in the domain of circle-related concepts. This deficiency becomes increasingly evident when students encounter difficulties in solving narrative problems, especially those that necessitate adaptation to

a context or question format distinct from the exemplary scenarios. This phenomenon can be attributed to a deficiency in critical thinking and problem-solving skills, which are fundamental components of mathematical literacy (OECD, 2019). Students' reliance solely on exemplary questions indicates a propensity for memorization-based learning patterns or specific examples. Furthermore, the low level of interest in mathematics education further exacerbates the gap in students' understanding of this subject matter. In theory, this gap could be attributed to a lack of learning that emphasizes the acquisition of conceptual understanding and contextual applications. In such instances, an approach such as project-based learning (PjBL) emerges as a potential solution to foster in-depth comprehension of concepts.

The analysis of the student worksheets utilized revealed that the student worksheets available in the mathematics textbooks are inadequate to support the learning process, both within the classroom and in the library. The student worksheets employed are static and lack the capacity to foster critical thinking or collaborative skills. Consequently, the researcher designed a student worksheet based on Project Based Learning (PjBL) with the objective of providing an effective means of supporting mathematics learning and minimizing the time allocated for learning. Student worksheets are designed to facilitate students' problem-solving skills by providing structured guidance and examples. These worksheets encourage students to articulate their reasoning and facilitate constructive dialogue with peers by facilitating the exchange of ideas and responses. Additionally, it invites students to express other individuals' ideas using their own language.

Analysis of the worksheets available in mathematics textbooks highlights a fundamental weakness, namely the lack of flexibility and stimulation of critical and collaborative thinking skills. In the context of modern education, project-based learning (PjBL) is one effective approach to address this problem. PjBL is designed to actively engage students in the learning process through relevant projects, which not only strengthen conceptual understanding but also foster 21st-century skills such as collaboration, communication, and creativity (Thomas, 2000). The importance of using learning methods such as PjBL is supported by previous research showing that project-based learning can improve students' critical thinking skills, collaboration, and conceptual understanding (Bell, 2010). By designing PjBL-based student worksheets, researchers seek to provide concrete solutions to increase student engagement and reduce wasted learning time. These student worksheets are meticulously crafted to not only facilitate students' comprehension of problem-solving methodologies but also to foster critical thinking, receptivity to feedback, and the ability to assimilate and modify the ideas of others to align with their own understanding. This pedagogical approach aligns seamlessly with the constructivist principles, which underscore the notion that learning is an active and collaborative process (Vygotsky, 1978).

Design

The selection of circles as a learning topic, particularly the circumference and area of circles, demonstrates the researcher's efforts to address conceptual challenges commonly encountered by 8th-grade students. This material presents a higher level of abstraction, which aligns with students' cognitive development according to Piaget's cognitive development theory (1972). At the age of 13-14 years, students transition from concrete operations to formal operations, enabling them to think abstractly and solve problems logically. However, they still require support through visual aids or concrete steps to comprehend abstract concepts (Wadsworth, 2004).

The learning model developed by the researcher not only considers the practical relevance of the material but also the pedagogical approach that fosters student engagement. This is crucial to establish a connection between mathematical theory and its practical applications in the real world. This strategy aligns with the contextual learning approach, which seeks to enhance the significance of learning by linking academic concepts to students' real-life experiences (Johnson, 2002).

The design of student worksheets tailored to students' interests, content, presentation, and language standards reflects the researcher's commitment to creating engaging and effective learning materials. Beyond enhancing comprehension, this design aims to motivate students

throughout the learning process. Adjusting language to students' ability levels is paramount to ensure that instructions on the student worksheet are easily comprehensible without causing confusion, in accordance with the principle of scaffolding in learning (Wood et al., 1976).

The student worksheet employs the Project Based Learning (PjBL) model, structured around six fundamental components: initiating essential questions, designing a project plan, creating a project schedule, monitoring student progress and project development, assessing project outcomes, and evaluating personal experiences. The layout of the student worksheet was meticulously designed using Canva, incorporating images from the insert menu and reputable internet sources. The design is printed on A4 paper with 1/1.5 spacing, 12-point font, and Times New Roman font complemented by Comic Sans MS for visual appeal. The student worksheet comprises 39 pages, comprising various sections, including a cover, author's name, foreword, PjBL model, table of contents, core competencies, basic competencies, indicators, concept maps, materials, activities 1-3, practice questions, and a concluding section that includes a bibliography.

Development

During the development phase, the product underwent validation through two types of validation: validation by material experts and design experts. Validation of student worksheets was conducted by three experts: two material experts and one design expert. Validation employed a Likert scale to assess the feasibility of content, presentation of material, elements of student worksheets, and language. The product development stage prioritizes validation by experts to ensure the quality and suitability of the product to educational standards. Validation by material experts focuses on the appropriateness of the content and presentation of the material, while validation by design experts assesses aesthetic and layout aspects, including ease of use and visual appeal. The utilization of a Likert scale facilitates systematic quantitative measurement, enabling objective analysis of validation results (Joshi et al., 2015).

Based on the validation results by material experts, it was determined that the student worksheets achieved an average score of 84% (very valid category) in terms of content feasibility. Additionally, the aspect of material presentation received an average score of 86.5% (very valid category). The validation results by design experts indicated that the elements of student worksheets obtained an average score of 86% (very valid category), while the aspect of language received an average score of 88% (very valid category).

The average score of 84% for content suitability indicates that the student worksheets are highly suitable to the learning material's requirements. This score reflects conceptual accuracy, relevance to the curriculum, and adequate depth of the material. Furthermore, the score of 86.5% for material presentation demonstrates that the student worksheets are well-designed to support student comprehension. Effective presentation involves a logical structure, supportive visualizations, and a variety of information delivery methods, which are crucial for enhancing student engagement (Reigeluth, 1999).

Design validation yielded a score of 86% for student worksheet elements and 88% for language, indicating that the student worksheets are not only visually appealing but also communicative. Design elements such as aesthetics, intuitive layout, and visual balance contribute to a superior learning experience. Additionally, language validation ensures that the instructions and descriptions in the student worksheets are easily comprehensible by students without causing ambiguity, aligning with the principles of effective communication in learning (Mayer, 2009).

Based on the validation results, the developed student worksheets are classified as highly valid and suitable for educational contexts. This demonstrates the effectiveness of an expert validation-based approach in enhancing the quality of educational products. Comprehensive validation ensures that the product not only adheres to academic standards but also remains relevant, engaging, and user-friendly for students.

Implementation

At the implementation stage, the researcher conducted a practicality and effectiveness test of the product developed. The practicality test assessed the extent to which student worksheets based on Project Based Learning (PjBL) could be effectively applied in classroom learning.

Product Practicality

Following the analysis, design, and development stages, the revised student worksheets, based on input from the validator, were tested on students. The field trial was conducted in class 8-c MTs N 2 Padangsidimpuan, comprising 25 students. The purpose of this trial was to determine whether the PjBL-based student worksheets met the practicality aspects in learning activities.

The instruments used to measure the practicality of student worksheets included observation sheets for the implementation of learning and student response questionnaires. During the learning activities, the researcher was assisted by an observer whose role was to observe the implementation of learning. The trial was conducted in three meetings, with different materials at each meeting. The results of the observation sheets indicated that all aspects of learning using PjBL-based student worksheets were classified as practical. The results of the observation sheet are presented in Table 1.

Table 1. Data from observations of the learning process

No	Aspect	Percentage	Practicality Category
1	Introduction	70%	Practical
2	Core Activities	73.3%	Practical
3	Closing	76.6%	Practical
	Average	73.3%	Practical

Based on the observation results, all aspects of learning (introduction, core activities, and closing) have been categorized as practical, with an average score of 73.3%. This indicates that PjBL-based student worksheets have systematically supported the learning process. However, a lower score at the preliminary stage (70%) may suggest that the orientation process or initial motivation in learning still requires improvement. This stage is crucial for preparing students and enhancing their involvement in the learning process (Slavin, 2014). The results of the student response questionnaire on the student worksheets are presented in Table 2.

Table 2. Student response questionnaire results data

N	Analysis	Content Feasibility	Material Presentation	Elements of Student Worksheets	Language
25	$\sum Skor$	430	500	368	294
	x_1	71.66%	71.42%	73.6%	73.5%
	$\bar{x}$	72.55%			
	Category	Practical			

The questionnaire results demonstrated that the student worksheets effectively met the practical criteria, with an average score of 72.55%. The elements assessed, including content appropriateness, material presentation, design elements, and language usage, indicated that the student worksheets are well-suited for student learning. The highest scores were obtained in the areas of student worksheet elements (73.6%) and language (73.5%), suggesting that the layout and language employed were aligned with the needs of students. These aspects are crucial for ensuring that the instructions in the student worksheets are easily comprehensible and visually appealing, adhering to the principles of effective learning design (Mayer, 2009).

Subsequently, a comprehensive analysis was conducted to assess the practicality of the student worksheet in its entirety. This analysis integrated the observations and the teacher response

questionnaire results. The findings revealed that both instruments, the observation sheet and the student response questionnaire, exhibited practicality percentages classified as practical, with an overall average of 72.5%. The integration of observational data and questionnaire responses offers a holistic assessment of the practicality of student worksheets. The average score of 72.5% underscores the practicality of PjBL-based student worksheets in meeting the practical criteria for educational use. This finding demonstrates the positive impact of the project-based approach on the implementation of learning that actively engages students. The approach fosters students' critical thinking and collaboration abilities, aligning with the demands of 21st-century learning as outlined by Thomas (2000).

Product Effectiveness Assessment

Product effectiveness is assessed after the product meets the practicality criteria. The assessment involved analyzing student learning outcomes achieved through the utilization of PjBL-based instructional materials. Data on student learning outcomes were obtained through student practice scores recorded during the learning process and test results obtained after the conclusion of the learning period. Table 3 presents the effectiveness assessment results, which are based on the average scores obtained from students' daily assignments and student worksheet exercises.

Table 3. Effectiveness data from student learning outcomes

No	Aspects Assessed	Average	Percentage	Category
1	Students' daily assignments	0.888	88.8%	Very Effective
2	Students' worksheet activity exercises	0.8503	85.03%	Very Effective
Overall average learning outcomes		0.8691	86.91%	Very Effective

As evidenced by Table 3, the average score for students' daily assignments was 88.8%, categorized as highly effective. Similarly, the average score for the student worksheets was 85.03%, also categorized as highly effective. The overall average score was 86.91%, indicating that the student worksheets are highly effective in enhancing students' learning outcomes. The efficacy of the PjBL method is evident in its ability to foster active learning, collaborative problem-solving, and the practical application of knowledge in real-world scenarios (Thomas, 2000).

Furthermore, based on the students' learning outcome data, 23 students achieved individual mastery, which also met the criteria for classical mastery, as 92% of the students were successful. This instructional approach meets the criteria of at least 85% classical success, which is frequently employed as a benchmark for assessing the effectiveness of learning methods (Slavin, 2014). The high level of success demonstrated by PjBL-based student worksheets indicates their ability to cater to the diverse learning needs of students, minimize gaps in comprehension, and enhance their motivation to learn. Consequently, it can be concluded that the Project-Based Learning (PjBL) student worksheets effectively improved students' competencies and can be effectively utilized in learning activities. Overall, the results of the effectiveness test demonstrate that the PjBL-based student worksheets are highly effective, with an average score of 86.91%. This finding underscores the worksheets' suitability for use and their significant contribution to enhancing students' learning outcomes.

Evaluation

The evaluation phase in product development serves as the culmination of the previous development process, aiming to identify product deficiencies. This evaluation is the final step in ensuring that the product developed aligns with learning objectives and can be effectively implemented. Deficiencies discovered during this evaluation encompass various aspects, such as language clarity, image relevance, and connections between student worksheets and students' real-world experiences. The recognition of these deficiencies constitutes a component of a formative evaluation, which seeks to enhance the product's effectiveness and usability (Guskey, 2000).

The initial deficiency identified was the language that remained challenging for students to comprehend. This underscores the significance of employing language that aligns with the comprehension level of students in developing learning materials. Language that is excessively technical or intricate can impede students' comprehension and engagement in the learning process (Mayer, 2009). The second deficiency was the absence of images that were not pertinent to the real-world context. The incorporation of relevant and contextual images is crucial for enhancing students' comprehension and establishing a connection between the material and their daily life experiences (Harp & Mayer, 1997). The third deficiency was the use of abstract questions that lacked direct relevance to students' real-world experiences. To enhance the efficacy of learning, it is imperative to construct questions that resonate with students' lives, thereby enabling them to relate the learning to their daily experiences (Bransford, Brown, & Cocking, 2000).

Following the evaluation, the implementation results demonstrated the strengths of the PjBL-based student worksheets. These worksheets were found to be suitable to student learning needs, as they were designed to meet students' requirements for understanding the material through a relevant and contextual approach. Additionally, they provided an engaging learning experience by integrating practical activities that increased student engagement, aligning with constructivism theory which emphasizes learning through direct experience (Piaget, 1976). Furthermore, these worksheets encouraged active student involvement, fostering creativity during learning, which is crucial for developing 21st-century skills (Saavedra & Opfer, 2012). Lastly, they enhanced students' collaboration skills through discussions and collaborative tasks, which are essential aspects of project-based learning (Johnson & Johnson, 1994).

This evaluation confirms the validity and practicality of the PjBL-based student worksheet. Furthermore, it demonstrates its effectiveness in enhancing student engagement and skill development during the learning process. By addressing the identified deficiencies and fortifying its strengths, this student worksheet can become a highly effective learning resource.

CONCLUSIONS

The Student Worksheet, developed through the Project-Based Learning (PjBL) model, has been validated by experts and deemed suitable for use in the learning process. The content feasibility aspect received a score of 84%, categorized as very valid. The material presentation aspect achieved a score of 86.5%, also classified as very valid. The student worksheet elements aspect scored 86%, and the linguistic aspect obtained an 88% score, both falling under the very valid category. These results suggest that the developed student worksheet is highly appropriate for the intended educational purposes. The implementation of the student worksheet through the PjBL model demonstrated the effective facilitation of the learning process. The utilization of the designed worksheets significantly enhanced students' comprehension of the lesson and problem-solving abilities in real-life scenarios. The visually appealing presentation of the student worksheet contributed to a more engaging and enjoyable learning experience, mitigating boredom among students.

Furthermore, the average student learning outcomes in this study were categorized as good, indicating that students achieved the learning competencies and indicators set for the lesson. The attainment of both indicators of effectiveness underscores the student worksheet's high effectiveness in supporting student learning. However, a limitation of this study is the absence of male students in the class under investigation, which prevented a comparative analysis of the abilities and characteristics of male and female students in terms of engagement in activities or project-based tasks. Future research could benefit from a more diverse sample to explore potential gender differences in the application of PjBL-based student worksheet.

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